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FREQUENCY OF TERNARY FISSION IN URANIUM

New evidence concerning the frequency of the fission of uranium into three fragments of comparable mass by thermal neutrons has been obtained by Dr. A. Berthelot and co-workers H. de Laboulaye, C. Tzara and J. Studinovski of the French Atomic Energy Commission Laboratories at Fort Chatillon and Saclay near Paris. Preliminary results of this group establish an upper limit for the frequency of ternary fission, showing that it occurs less than once per thousand fissions. This figure is to be compared with the currently accepted estimate of the frequency of fission into three fragments all of which are heavier than an alpha-particle, namely, about once in eighty fissions.

Apparatus

An interesting cloud chamber technique has been employed in this investigation. A layer of uranium only about 10μgm/cm^2 thick was deposited on a formvar sheet about 20μgm/cm^2 thick which stretched across the center of a cylindrical cloud chamber. Parallel to the uranium strip and equidistant on opposite sides were two wires,

maintained respectively positive and negative relative to the uranium. The uranium was grounded, as were the top and walls of the chamber. Fissions were produced in the uranium by thermal neutrons from the pile at Fort Chatillon (Zoé). The pulse produced by the arrival at the positive wire (anode) of electrons formed in the chamber gas by fission fragments is used to actuate a circuit which removes the potential from the charged wires within a few microseconds of the time of fission. This pulse also initiates expansion of the chamber.

The technique possesses a number of advantages: the chamber is expanded only when ionizing radiation passes through it; the origin of the fission tracks is precisely defined as the thin uranium layer; and the time resolution is extremely good permitting the resolution of tracks formed more than a few microseconds apart. This excellent resolution arises from the difference in appearance of tracks of particles which pass through the sensitive region before or after the electron collecting field is removed. In both cases the track consists of dense ionization along the path of the particle, but in the former case the track also shows a diffuse cloud of ionization extending from the fission fragment's path to the anode. The cloud is due to negative ions formed by attachment of some of the electrons as they move toward the anode under the attractive field.

Apparent Ternary Fission Events

Dr. Berthelot and his associates have observed a number of apparent ternary fissions. These are cases where the tracks of two fission fragments are intersected by a third heavily ionizing track which has been produced simultaneously. However, the intersection of these tracks does not occur in the thin uranium layer. The third prong is therefore explained by Dr. Berthelot as being due to an atom of the chamber gas which is struck by one of the two fission fragments. A small

fraction of the observed three-pronged events occur so close to the uranium-formvar layer that it is not possible to state definitely from stereoscopic photographs that they do not originate in the uranium. Berthelot and his associates have obtained further evidence on such cases by studies of the frequency of occurrence per unit path length for triple events originating within and outside of the minimum resolvable distance from the uranium layer. The triple events were found to have the same probability of occurrence, within statistical error, regardless of whether the region of origin included the source or not. Furthermore, the distribution in range of the third fragments was observed to be independent of the location of origin. These observations served to set an upper limit to the frequency of ternary fission of one in a thousand.

COSMIC RAY CONGRESS ON UNSTABLE HEAVY PARTICLES

A Cosmic Ray Congress organized by the University of Toulouse under the sponsorship of the International Union of Pure and Applied Physics was held at Bagneres de Bigorre, France, from 6 - 12 July 1953. The conference was devoted to the discussion and interpretation of new results on unstable heavy particles of the cosmic radiation.

Proposed Notation for Heavy Unstable Particles

The following system of notation was recommended at the Bagneres Congress: (1) L-mesons (symbol L), π-mesons, μ-mesons, any other possible lighter meson; (2) K-mesons (symbol K), particles with mass intermediate between those of the π-meson and the proton, i.e., tau-, kappa-, chi-mesons; (3) Hyperons (symbol H), particles with mass intermediate between those of the proton and the deuteron. Hyperons carry capital Greek letters, mesons small Greek letters.

For cloud chamber events, the expressions V-event and S-event designate respectively the decay in

flight of a heavy particle and the decay or nuclear capture at rest.

Hyperons

The V_1^o particle is well established and carries the symbol Ω^o:

$$\Omega^o \longrightarrow p+\pi+37 \text{ Mev; half-life} = 3.3 \times 10^{-10} \text{ sec.}$$

It is now almost certain that the Ω^o particle is made out of a nucleon and represents a type of excited state of the neutron. At least four cases exist in which the Ω^o has been observed in a nuclear emulsion carried by a heavy fragment and decaying after the fragment has come to rest.

A new contribution brought forth at the Congress is the decay of a charged hyperon (super-proton):

$$H^{\pm} \longrightarrow n+\pi^{\pm} + (130 \text{ to } 135 \text{ Mev}).$$

The cloud chamber measurements of the California Institute of Technology group tend to confirm the cascade process, first observed at Manchester,

$V^{*-} \longrightarrow \Omega^o + \pi^-$. (The designation V^{*-} is tentative).

K-mesons

Evidence presented by Thompson (Indiana) and others at the Bagneres Congress seems to confirm the existence of the θ^o particle, formerly V_4^o of the V_2^o group;

$$\theta^{o} \longrightarrow \pi^{+} + \pi^{-} + (214 \pm 5 \text{ Mev}).$$

The θ^{o} mass is $971 \pm 10\ m_e$; this value is in close agreement with that of the τ-meson.

There is some evidence for two further particles; although it is not as definite as for the θ^{o} particle:

$$V_3^{o} \longrightarrow K + L + 60 \text{ Mev}$$

$$\tau^{o} \longrightarrow \pi^{+} + \pi^{-} + \pi^{o} + (< 75 \text{ Mev}).$$

Charged K-mesons (S, $V^{\pm}$, τ, κ, χ)

Photographic plate evidence brought forward at the Congress has given rather precise values for the tau-decay; most of these particles which come to rest and decay are positive:

$\tau^{\pm} \longrightarrow \pi^{\pm} + \pi^{+} + \pi^{-} + 72$ Mev; half-life $\sim 10^{-10}$ to 10^{-8} sec.

The mass of the tau-meson is about 970 m_e.

It is still an open question whether a charged tau can also decay into a charged and two neutral π's. The matter of the direct production of tau-mesons has not been settled either since heavy mesons ejected from nuclear disintegrations seem to show mass values of about 1200 (according to Perkins' measurements at Bristol). The remaining decays of the charged K-mesons are of the type

$$(i) \longrightarrow \mu^{\pm} + 2 \text{ light neutral particles},$$

$$(ii) \longrightarrow \pi^{\pm} + N^{o},$$

$$(iii) \longrightarrow \pi^{\pm} + \gamma.$$

The measured masses of all the primaries of these three processes are consistent with a single mass of 990 (according to emulsion experiments) and 922 (according to the Ecole Polytechnique cloud chamber work). This is considered to be significantly lower than the value of 1200 for ejected K-mesons.

The primary particle for process (i) is the original kappa (κ)-meson. Decay (ii) is the one ascribed to the chi (χ)-meson, but the evidence for its existence depends crucially on the identification on the secondaries as π-mesons. The third decay has been observed by the MIT group in cloud chambers recently and corresponds to the S-particle.

The question whether and how many of these four particles are identical, in the sense that they show alternative modes of decay of the same particle, has not been settled. There always exists some contradictory evidence against any attempt to combine two particles.

NEW DECAY EVENTS IN PHOTOGRAPHIC EMULSIONS

At a recent Cosmic Ray Conference at Bagneres, France, Prof. B. Peters of the Tata Institute of Fundamental Research, Bombay, India, presented very significant results on the decay of heavy unstable particles observed in a stack of stripped photographic emulsions. Particles which have been identified by this new technique thus far include several tau- and K-mesons which come to rest before decaying; further, the first evidence for the existence of negative heavy mesons has been found. Peters has also identified four events which probably represent the decay of neutral heavy particles. All events were observed in a solid block

of emulsion consisting of twenty-four emulsion sheets 6" x 4", each 600 microns thick which were placed together in a stripped condition (i.e., without glass) and exposed in the stratosphere at geomagnetic latitude 19°. After exposure these emulsion sheets were mounted on glass plates and carefully aligned on slides such that particle tracks could be traced through the entire block.

With such an emulsion arrangement it is comparatively easy to identify various types of particles and trace them to their origin, since the track length available for measurement is frequently of the order of several cms.

Tau-Mesons

From careful measurements of three tau-decays (each decaying into three π-mesons) the mass of the tau-meson has been deduced as 969.3 ± 1.7 electron masses with a Q-value of 72.2 ± 0.8 Mev. Thanks to the stripped emulsion technique, more evidence has now been obtained for the sign of the π-mesons (and therefore an indication of the sign of τ-mesons). Five π-mesons have been observed to stop in the emulsion; four of these are positive.

Positive K-Mesons

Four examples have been found of heavy mesons which come to rest emitting only one light particle (π- or μ-meson). The best mass value for these K-mesons is 1025 ± 50 m_e. A new method was employed in the measurements of multiple Coulomb scattering; it consisted of varying the cell length as a function of residual range of the particle in the emulsion.

Negative Heavy Mesons

For the first time evidence has been obtained that some heavy mesons are captured by nuclei, leading to stars observed in the emulsion. Four examples of

these negatively-charged heavy mesons were observed. The mass of this meson is approximately 1000 m_e; it may thus represent the negative counterpart of the tau-meson or kappa-meson. (Later discussions in the conference made it appear more likely that they are the negative counterpart of the tau-meson).

V_1^o Particles

In tracing 85 π-mesons, which come to rest, to their origin in the emulsion stack, two cases have been found which seem to resemble the V_1^o decays observed in cloud chambers, namely $V_1^o \rightarrow p + \pi^-$. The parent particle in both cases has a mass of about 2185 m_e with a Q-value of 37 - 38 Mev.

CLOUD CHAMBER MASS MEASUREMENTS

The double cloud chamber of the Ecole Polytechnique, Paris, described in Technical Report CNRL-69-51 has been put into operation at the Pic du Midi (altitude 2800 meters) during recent months. Both chambers have extremely large volumes, 70 x 76 x 50 cm. With the top chamber in a field of 2600 gauss, it is possible to resolve momenta as high as 12 Bev. The bottom chamber is similar to the top one, but has no magnetic field and contains seven lead plates 0.7 cm thick and six carbon plates each 1.5 cm thick.

This apparatus has been used by Dr. B. P. Gregory, Dr. C. Peyrou and others from the Ecole Polytechnique to measure, by means of the momentum-range method, the masses of heavy mesons produced in nuclear interactions in the lead above the top chamber. Accordingly, these scientists have observed the curvature (and therefore momentum) of four heavy particles in the top chamber and their subsequent ranges in the bottom chamber. The mean mass of these so-called S-particles has been obtained as

922 $\pm$ 41 m_e. This accuracy represents a very significant contribution to the identification and understanding of S-particles; they may now be identified with the K-mesons observed in photographic emulsions. This experiment represents the first successful determination of heavy meson masses in a cloud chamber to the degree of accuracy cited.

THE PHOTOCHEMISTRY OF SELENIUM

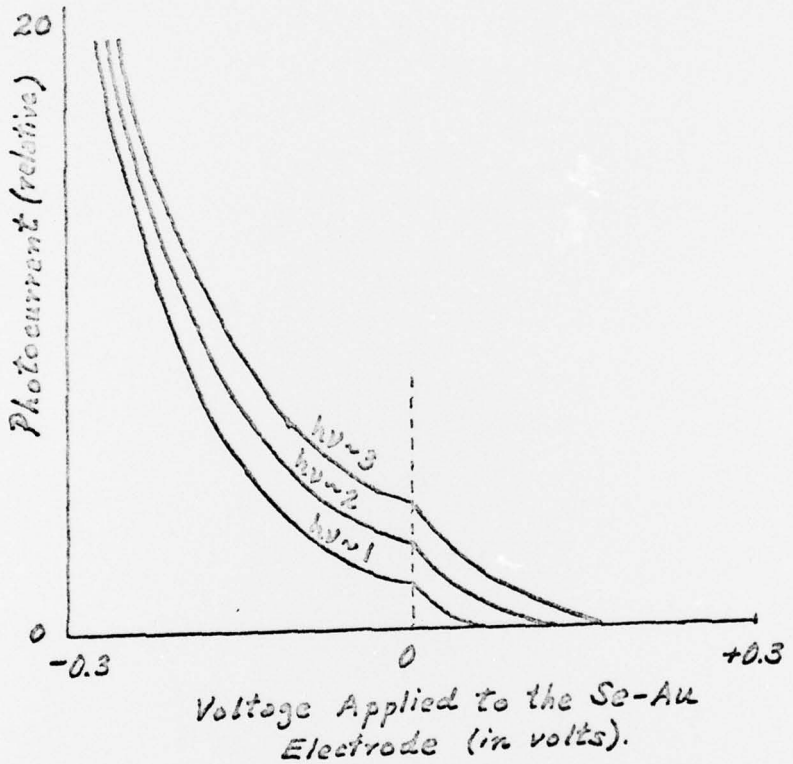
In a recent paper (JCS, 855 (1953)) Dr. R. W. Pittman (Birkbeck College, London) discussed the photogalvanic effects observed with red selenium and showed that a gold electrode coated with red selenium and immersed in aqueous hydrochloric acid behaves reversibly on illumination, the red selenium acting as a cathodic depolarizer. This effect was explained in terms of a localized adsorption of hydrogen atoms on the surface of the selenium resulting in the compound HSe_8.

Photochemistry of Grey Selenium

Pittman has recently used a similar experimental set-up to study the photo-conduction of grey selenium, but the results obtained have been entirely different. When the photo-current is plotted as a function of the voltage applied to the selenium-coated gold electrode, the curves shown below are obtained at various illuminations; voltages are measured with respect to the other electrode.

It is immediately apparent that a discontinuity in these curves exists at the null point, i.e., $V = 0$, and therefore it is likely that two separate processes are taking place, one for negative voltages and another for positive. It is also found that the "null" current is directly proportional to the strength of the illumination. When the gaseous products liberated at the selenium-gold electrode were analyzed, it was found

that hydrogen selenide was being liberated when the applied voltage was zero. Since the currents at this point were rather small, Pittman attempted to obtain larger quantities of hydrogen selenide by operating in the region of negative voltage and at high photocurrent. However, in this region no hydrogen selenide was liberated, but instead hydrogen gas was formed on the selenium surface.



Photoconductivity for a Grey Se Electrode in HCl Solution

Possible Explanation of Chemical Reactions Involved

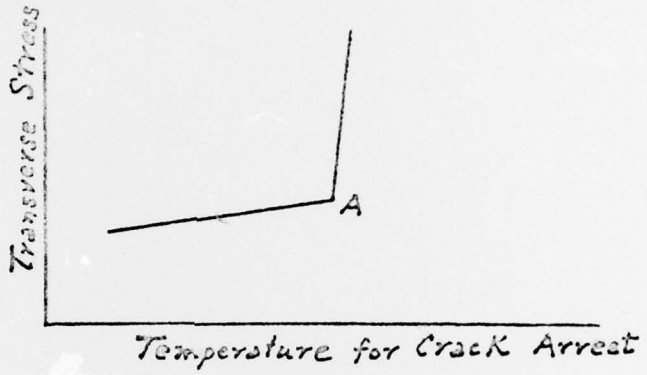
Pittman has advanced the following hypotheses to explain these results. With no applied voltage, i.e., at the null point, photoelectrons are emitted on illumination, and a double layer is formed at the selenide surface consisting of electrons and positive holes. Some of the emitted photoelectrons combine with the hydrogen ions in solution to form hydrogen atoms in the usual manner. Since the Se^{-} entity at the surface has an odd number of electrons and the hydrogen atom also contains an odd number of electrons, it has been suggested that they combine, resulting in an HSe^{-} ion at the surface. This ion being unstable immediately breaks down into the hydrogen selenide ion, HSe^{-}, with the formation of two positive holes, which then allows positive hole conduction through the selenium to the gold metal interface. The HSe^{-} ion combines rapidly with the hydrogen ions in solution forming hydrogen selenide gas which is liberated from the surface. Thus, positive hole conduction can occur for zero or very small positive potentials on the selenium-coated gold electrode, but the current should decrease rapidly with increasing positive voltage; this result agrees with the experimentally observed data.

With negative applied voltages the photoemission of an electron again results in a positive hole near the surface. Owing to the negative potential on the selenium-gold electrode, the positive hole moves rapidly through the selenium layer towards the gold core, and hence no combination of a positive hole with a hydrogen atom can occur. Instead the hydrogen atoms combine giving molecular hydrogen.

THE PROPAGATION OF BRITTLE FRACTURE IN STEEL

T. S. Robertson and D. le M. Hunt of the Naval Construction Research Establishment, Scotland, have conducted some interesting work on the propagation of brittle fracture in steel. In a previously published

paper (Engineering, 172, 444 (1951)) it was shown that there is a critical relationship between the stress transverse to the crack and the temperature at which the crack will no longer propagate. This relationship is shown schematically below.

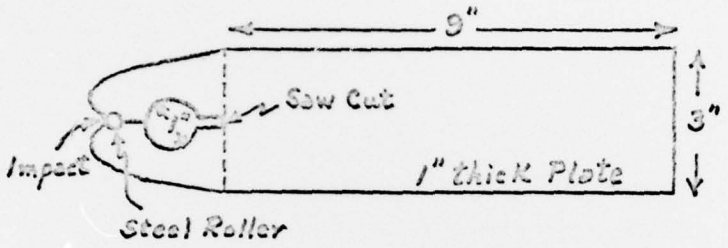


Critical Relationship between Transverse Stress and Temperature for Crack Arrest

The stress at point A varies with the steels currently used in ship construction from 32,500 to 8,800 psi; the temperature at this point is in the range of ambient temperatures experienced in service. The critical stress-temperature relationship (left branch of curve) which occurs within the average range of service stresses is very important, since a crack once started will propagate catastrophically if the general stress level is above that corresponding to the temperature for arrest. While the previous work yielded practical information of immediate use, it was desired to seek data of a more fundamental nature. With this aim the original test which involves a temperature gradient along the test piece was modified by the use of a test piece maintained at a constant temperature with a stress gradient.

Measurement of Force for Crack Propagation

The specimen used retained the main crack-starting features of the original type specimen, but in addition a steel roller was inserted at the end to give a determinative force system free from bending moments. A sketch of the specimen is shown in the following:



Specimen for Studying Crack Propagation Force

The specimen was cooled to the testing temperature (from 0° to -60°C), and was mounted in a jig which supported and insulated it. The impact for producing a brittle running crack was provided by a bolt gun, the impulse from which exists for sufficient time to cause the crown of the test piece to yield after the shock has started a running crack. When the impulse is over the crack still propagates under the elastic forces stored in the yielded material. These elastic forces make up a determinative system and must pass through the roller pin and normal to the direction of the crack. The crack stops when its length increases sufficiently to relax these elastic forces.

The measurement of the forces is made after the test has been completed. A micrometer measurement is made across the end of the test specimen to determine the increase in this dimension. The pin is then

removed and the crack partially closes, although it does not close completely for two reasons: (a) the re-entrant nature of the newly created surface prevents complete closure, and (b) the crack propagates at a high speed through material which has no time to yield and arrests because the stress at the root falls to a value too low for propagation; however, as soon as the crack has arrested, yield at the root takes place and for this reason also the crack cannot close completely.

Loading arms are mounted at the end of the test specimen, and width measurements are made to obtain a load-deflection graph. This graph is a straight line, the slope of which gives the combined stiffness of the two cantilevers separated by the crack. The actual force available for propagation at the instant of arrest is given by the stiffness multiplied by the total deflection before removal of the pin; i.e., the increase in width across the specimen relative to the value before test.

Experimental Result

In an investigation to determine how the force of propagation varies with crack length, charges of different strength were used in the bolt gun to produce cracks in 1" thick steel plates tested at the same uniform temperature. The results of these tests led to the conclusion that the force for propagation at a given temperature and for a given material is constant and independent of the crack length. This conclusion was arrived at only by analysis of experimental results and was wholly unexpected. The force for propagation is the limiting force below which propagation will cease, and there is a corresponding limiting surface energy for crack propagation. Future work on this problem will include various thicknesses of plate.

Other topics presented at a Conference on Brittle Fracture in Steel, held in Glasgow, are discussed in Technical Report CNRL-94-53.

PHASE CONTRAST OBSERVATIONS OF THE PROCESS OF HEMOLYSIS IN SALAMANDER ERYTHROCYTES

The experiments of Dr. W. D. Trotter, University of Oxford, using salamander erythrocytes indicate that the process of hemolysis varies somewhat with the hemolysing agents used. The large size of salamander erythrocytes makes them especially suitable for studying the visible changes accompanying hemolysis. The cells were hemolysed by a variety of agents including water, acids, alkalis, saponin, digitonin, bile salts, soaps, anionic and cationic detergents. Hemolysis was accompanied by changes in optical properties, size, and shape of the cell as a whole, and in the shape and optical appearance of the nucleus. The appearance of the cell varied with the method of producing hemolysis.

Alkalis produced bizarre changes in shape after which the distorted cells again became spherical and finally underwent rapid complete cytolysis. Water produced spherical prolytic cells, the ghosts being either circular or elliptical in outline, and in many cases showing partial or complete extrusion of the nucleus. Acids produced grossly distended ghosts exhibiting an apparently rigid fibrillar structure in the part of the "membrane" forming the original rim of the cell.

The majority of natural and synthetic surface active agents gave ghosts of elliptical outline when used in high concentration, and a large proportion of circular ghosts with weaker concentrations. With some lysins hemolysis was succeeded by gross swelling and final dissolution of the nucleus.

MORPHOLOGY OF THE COLLATERAL CIRCULATION FOLLOWING COMPLETE INTERRUPTION OF THE ABDOMINAL AORTA

Dr. J. L. Braithwaite, University of Liverpool, has studied the origins of the branches of the abdominal aorta in twenty rats (as a control) and carried out ligation experiments in thirty-six others. The sites of interruption varied between the origin of the celiac

artery and a point just proximal to the aortic bifurcation. In the twenty-nine animals surviving operation the morphology of the collateral circulation was studied by sacrificing the rats at periods up to three months after operation, with radiographic and dissection techniques being employed to elucidate the results. Ensuing complications were also noted.

The results demonstrate that the abdominal aorta can be ligated with comparative safety at all levels distal to the origin of the left renal artery; all fatalities in the above study except one followed ligations at levels proximal to the renal artery. The macroscopic collateral channels (both visceral and parietal) became noticeably enlarged after a period of about four days, although the degree of enlargment of these varied with the site of ligation. The most important anastomotic channels were the spermatic, mesenteric, ureteric, interlumbar and those occurring in the body wall. Additionally, a more localized plexus of fine vessels was manifest in the region of the ligation site.

The main complication following these procedures was a temporary paralysis of the hind extremities lasting from two to three days, although necrosis of the tail occurred in two instances, and gangrene of the left uterine horn in one.

TECHNICAL REPORTS OF ONRL

The following reports have been forwarded to ONR, Washington, since the last issue of ESN.

ONRL-40-53 "Conference on the Physics of Ionized Gases" by J. K. Beling and S. F. Singer

ONRL-82-53 "Electron Impact Spectroscopy" by G. J. Szasz

ONRL-92-53 "Acoustics Research at the University of Oslo" by J. R. Reitz

CNRL-94-53 "Conference on Brittle Fracture in Steel" by E. Epremian

CNRL-95-53 "Computer for Phase Analysis in Elastic Scattering" by J. K. Beling

PERSONAL NEWS ITEMS

In the course of his lecture on Paramagnetic Resonance at the Annual Meeting of the Societe de Chimie Physique (Paris), Dr. B. M. Kozyrev (Kazan, U.S.S.R.) referred to the death, about a year ago, of Professor J. Frenkel, theoretical physicist. It is believed that Professor Frenkel's death has not so far been known in the United States or in Western Europe.

Professor E. D. Adrian of Cambridge University was recently presented with the gold Albert Medal of the Royal Society of Arts for his outstanding contributions in the field of neurophysiology.

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